**Faculty of Engineering**

# Development of Rapid Alignment Polisher's Hand (RAPH) for Cross-section Polishing in Physical Failure Analysis

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# Development of Rapid Alignment Polisher's Hand (Raph) for Cross-Section Polishing in Physical Failure Analysis

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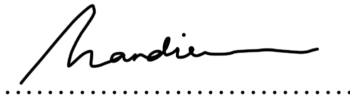
## DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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## ABSTRACT

X-FAB uses patented process technology to produce analog/mixed-signal ICs. As a pure-play foundry, X-FAB does not produce its own integrated circuits (ICs), instead manufacturing them using designs produced by its clients or other parties in collaboration, mostly using X-FAB's portfolio of modular, highly specialized proprietary process technologies and intellectual property (IP). Chemical Mechanical Polishing (CMP) cross-sectioning technique has been recognized for many years as failure analysis fundamental tool for examining depth-related profile of a sample. Therefore, it is a precious tool in semiconductor industry as its exclusive characteristic of providing entry into a third dimension in a two-dimension world. Process levels can be micro sectioned and capability to inspect layer-by-layer made this method crucial in gathering information on fabrication parameters and on defects. Another advantage of CMP cross-sectioning is its wide area of observation as compared to other cross-sectioning methods such as Focus Ion Beam (FIB). CMP cross-sectioning requires high skilled failure analyst and require couple of hours to complete a section of reasonable complexity of target. Typically, CMP cross-sectioning is performed in three basic steps: physical mounting, coarse grind and final polish. These three steps are time consuming particularly during coarse grind, the analyst need to realign the target before it reaches to final polish. Any technology that can reduce the polishing turnaround time is most welcomed on this day. Allied High-Tech Products. Inc. is a well-known maker of precision grinders and polishers. This research will provide a new idea of design and fabrication of the anticipated polisher fixture called Rapid Alignment Polisher Stage (RAPS), which will assist a fast, controllable, and accurate target alignment which current method is lacked off. This product is believed able to decrease the polishing turnaround time significantly.

**Keywords:** Physical Failure Analysis (PFA), Silicon on Insulator (SOI), Chemical Mechanical Polishing (CMP)

***Pembangunan Rapid Alignment Polisher's Hand (Raph) untuk Penggilapan Keratan Rentas dalam Analisis Kegagalan Fizikal***

## *ABSTRAK*

*Teknik penarataan kimia dan mekanikal (CMP) telah diiktiraf selama bertahun-tahun sebagai alat analisis kegagalan asas untuk memeriksa profil kedalaman. Ia adalah alat eksklusif dalam industri semikonduktor sebagai pengukuran ke dimensi ketiga dalam dunia dua dimensi. Tahap penganalisisan adalah pada sekala micro sectioned dan kemampuan untuk memeriksa lapisan demi lapisan membuat kaedah ini penting dalam mengumpul parameter fabrikasi dan kecacatan. Satu lagi kelebihan CMP ialah keluasan pemerhatiann yang lebih berbanding dengan kaedah keratan restas yang lain seperti Focus Ion Beam (FIB). Penganalisis yang mahir memerlukan beberapa jam untuk melengkapkan satu kerja keratan rentas struktur sasaran. Secara tipikal, CMP keratan rentas dilakukan dalam tiga langkah asas: pemasangan fizikal, penrataan kasar (rough polishing) dan penrataan akhir (final polishing). Langkah ini memakan masa terutama untuk penjajaran penrataan kasar. Penganalisis perlu memastikan penjajran yang tempat sebelum mencapai penrataan akhir. Teknologi yang boleh mengurangkan masa penjajaran rataan adalah sangat diperlukan sekarang untuk menigkatkan produktiviti penrataan. Penyelidik mempunyai pengalaman selama 14 tahun menggunakan alat Allied MultiPrep ™ Polishing. Allied High Tech Products. Inc. adalah pembuat terkenal dan terbaik alat penrataan (polishing machine). Penyelidikan ini akan memberikan idea baru reka bentuk dan fabrikasi satu bahagian dalam mesin penrataan yang dipanggil Rapid Alignment Polisher's Hand (RAPH). Ini justeru membantu mengurangkan masa penjajaran sasaran dengan kawalan yang cepat dan tepat disamping mengekalkan mutu penrataan keratan rentas (cross-section polishing).*

***Kata kunci:*** *Kegagalan Fizikal (PFA)l, Silikon Pada Penebat (SOI), Penrataan Kimia Mekanikal (CMP).*

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## LIST OF ABBREVIATIONS

| adj | Adjusted |
|---|---|
| ANOVA | Analysis of variance |
| BHF | Buffered Oxide Etch |
| BOX | Buried oxide |
| CDA | Compress dry air |
| CH3COOH | Acetic Acid |
| CMOS | Complementary Metal Oxide Semiconductor |
| CMP | Chemical Mechanical Polishing |
| Cu | Copper |
| CVD | Chemical Vapor Disposition |
| DI | De-ionized |
| DOE | Design of Experiment |
| DTI | Deep Trench Isolation |
| EBR | Edge Bead Removal |
| FA | Failure Analysis |
| FLGT | Floating gate |
| GOX | Gate Oxide |
| HF | Hydrofluoric |
| H2O | Water |
| H2O2 | Hydrogen Peroxide |
| IBM | International Business Machine |
| IC | Integrated circuits |
| ILD | Inter-level dielectric layer |

| | |
|---|---|
| IMD | Intermetal Dielectric |
| IP | intellectual property |
| Lab | Laboratory |
| NCD | Nanocrystalline diamond |
| NHO3 | Nitric Acid |
| NH4OH | Ammonium Hydroxide |
| PFA | Physical failure analysis |
| PFIB | Plasma Focus Ion Beam |
| PI | Polyimide |
| RAPH | Rapid Alignment Polisher Hand |
| Rcu | Copper polishing rate |
| RFIC | Radio frequency integrated circuits |
| RIE | Reactive Ion Etching |
| ROI | Region of interest |
| Rox | Oxide polishing rate |
| rpm | Radius per minute |
| SC1 | Standard Clean 1 |
| SEM | Scanning Electron Microscopy |
| SiO2 | Silicon Dioxide |
| SOC | Systems-on-chip |
| SOI | Silicon on Insulator |
| SRAM | Random-Access Memory |
| stdev | Standard deviation |
| STI | Shallow Trench Isolation |
| TMAH | Tetramethylammonium hydroxide |

| | |
|---|---|
| una | Unadjusted |

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

Chemical Mechanical Polishing (CMP) is a basic approach to allow extremely flat and smooth surface be produced at several critical steps in semiconductor manufacturing process flow (Banerjee et al., 2008). International Business Machine (IBM) invented CMP in the semiconductor industry in late 80's to enable more metal layers to be included in their integrated circuits (IC) (Woodie, 2007). The idea was to perform planarization of oxide inter-level dielectric layers (ILD) by depositing metal layer and add another layer of oxide. These layers of oxides must be smooth and not wavy to enable more metal layers to be stacked in IC. Without CMP, layers stacking will follow previous material's topology. This will cause metal short if multiple metal layers are deployed in IC. CMP has been carried out by means of the special liquids containing particles of an abrasive material and alkaline chemical substances (Khmelev et al., 2006). CMP process is used to planarize ILD since last two decades and currently it is employed for tungsten contacts, vias, shallow trench isolation (STI), and for copper interconnects in dual damascene architecture (Banerjee et al., 2008). In X-Fab Sarawak Sdn. Bhd. Failure Analysis (FA) laboratory, Allied Multi-Prep Polisher machine Figure 1.1 uses CMP process to perform a physical sample de-processing. De-processing is a process to remove thin film layers which applied in the wafer fab in reverse order during physical failure analysis (PFA) (Wagner, 2001). Allied Multi-Prep Polisher machine is capable to perform sample de-processing using parallel lap and cross-section polishing techniques. Parallel lap polishing technique is employed to delayer or remove thin layers such as Nitrides, Oxides, Aluminium, and low dielectric constant materials inside the